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Request for grant of a patent

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The Patent Office
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1. Your reference

02445 GB

2. Patent application number
(The Patent Office will fill in this part)

0229855.2

23 DEC 2002

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

847055 7/022

Invensys Controls UK Ltd
Invensys House
Carlisle Place
London
SW1P 1BX

Patents ADP number *(if you know it)*

If the applicant is a corporate body, give the country/state of its incorporation

United Kingdom

4. Title of the invention

Diagnostic Tool for an Energy Conversion Appliance

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

Mr J R Badger
Invensys Intellectual Property
P O Box 8433
Redditch, B98 0DW
United Kingdom

8495510001

Patents ADP number *(if you know it)*

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
GB	222137.2	24 September 2002

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*

a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d))

YES

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Continuation sheets of this form	0
Description	8
Claim(s)	4
Abstract	0
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Priority documents	0
Translations of priority documents	0
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	0
Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	1
Any other documents *(please specify)*	0

11. I/We request the grant of a patent on the basis of this application.

Signature J. R Badger Date 23/12/02

12. Name and daytime telephone number of person to contact in the United Kingdom — J R Badger 01527 838264

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DIAGNOSTIC TOOL FOR AN ENERGY CONVERSION APPLIANCE

The present invention relates to a diagnostic tool for and method of monitoring an energy conversion appliance and particularly, but not exclusively, to a tool for an appliance which utilises more than one form of energy and / or medium. The diagnostic tool may, for example, be used with heating, ventilating and air conditioning appliances.

Increasingly, diagnostic tools are being embedded into control systems of appliances. Not only does this allow service engineers to diagnose faults speedily, but, with the rapid increase of connectivity technology, diagnostic data can be sent via telephone or other communication channels to "back-end" systems where sophisticated diagnostic and predictive algorithms can be run using processing power greater than that which it is economic to provide in each appliance.

The advantage of a predictive diagnostic tool to the service provider is that fault repair can be accomplished in one visit to the customer's premises, while the predictive nature of the system means that preventative maintenance can be undertaken during annual service visits.

The advantages to the customer include reduced system problems and a more rapid repair of faults.

Currently these systems are mainly applied to new appliances, which means that it will be many years before the installed population of these devices reaches a level to make economic sense to the service provider.

One type of appliance to which the present invention seeks to relate is heating and air conditioning appliances employing combustion processes for the heating source, and the present invention seeks to provide a diagnostic tool which is retro-fittable for use in a domestic central heating boiler.

In types of systems such as domestic heating systems the sequence of the control functions is critical to the safe operation of the appliance. Many of the international regulations for these types of appliances dictate the correct operating sequence that must apply.

Thus monitoring this sequence and detecting variations in and interruptions to the sequence provides significant and important diagnostic data.

To duplicate the data available to and obtained from an embedded diagnostic tool provided as part of an original appliance installation by the use of a retrofitted diagnostic device hitherto has required obtaining access to the control and sensor signals within the appliance control system. The intrusive nature of this activity potentially compromises the integrity of the control or, at the least, is very time consuming in installation.

The present invention seeks to provide a diagnostic tool which is well suited for use as a retrofit diagnostic tool and that can be installed easily into an existing appliance. The invention seeks also to provide a diagnostic tool which is able to extract from an appliance data which is additional to, or differs from, that available using a conventional embedded system, but which provides an equal, if not improved, functionality. Another object of the invention is to seek to provide a diagnostic tool which is minimally intrusive into the appliance control system and thus simple to install.

In accordance with one aspect of the present invention there is provided a diagnostic tool for an energy conversion appliance, said diagnostic tool comprising a sound receiving transducer coupled to a sound recognition engine, alternatively referred to herein as output means to identify, discriminate and log the acoustic signatures of events within the operating sequence of an appliance.

The word "event" is used herein to encompass a change of state of a component, or components, of the operating or control system of the appliance. As an example FIG 1 tabulates a typical event sequence of a simple domestic gas central heating boiler.

Typically, the sound recognition engine could be an adaptation of a type of voice recognition system known per se. These systems, commonly found in mobile telephones and other applications requiring voice tagging or control, are very robust in the presence of background noise and the technology is becoming well known and reliable.

In accordance with another aspect of the present invention there is provided a method of monitoring an energy conversion appliance, said method comprising: -

- providing a sound receiving transducer and positioning said transducer to receive sound signals emitted by the appliance, and
- providing output means associated with said sound receiving transducer, said output means being responsive to the sound emitted by the appliance.

Said method may comprise establishing a sound profile which is concomitant with proper functioning of at least a part of the appliance, and said output means may be responsive to occurrences of the sound emitted the appliance departing from said sound profile. The output means may be responsive only if the emitted sound (whether for example, frequency, duration or level thereof) lies beyond (above or below) a threshold level.

The references herein to a sound signal include but are not limited to sound signals audible to the human ear. The expression "sound signal(s)" is used herein to refer to any frequency of pressure wave signal transmitted through a gas.

The output means may comprise means operated within the vicinity of an appliance to identify, discriminate and log the acoustic signatures of events within the operating sequence of an appliance or transmit signals related thereto to remote data processing means.

The profile may be specific to substantially only one relationship between received sound and time (for example variation or uniformity of sound level over a fixed time interval). Alternatively the sound profile may comprise upper and lower limits of sound level and / or time duration such that the overall profile encompasses a plurality of specific relationships all of which are concomitant with the proper functioning of the appliance.

The profile may be one which comprises upper and lower sound level limits the difference between which varies non-uniformly over the typical time period of a monitored event.

The diagnostic tool and method for monitoring an energy conversion appliance in accordance with the present invention may be employed for the purpose of trend analysis or non emergency monitoring, for example monitoring by a so called "backend" computer system which receives data from a plurality of customers. Data may be transmitted from the output means on a regular, e.g. daily basis for example to provide information concerning what has happened within a central heating boiler even though the data relates to events that may all be within an acceptable sound profile. For example data may be transmitted concerning the period of use of a fan motor and the e.g. daily reports can then be assimilated by the centrally located backend computer power to analyse any significant variation of boiler performance and or highlight the need for servicing. As a further example, the data may be assimilated to provide a timely indication as to whether there is potential need for precautionary replacement of any one component, such as an extensively used fan motor, at the time of next routine servicing of the appliance.

Additionally or alternatively the diagnostic tool provided at the appliance may incorporate means to generate an alarm signal, either in the vicinity of the appliance or remotely at a central monitoring station, in the event that the diagnostic tool detects a sound profile which departs from a predetermined profile and is indicative of failure or impending failure of at least a component part of the appliance.

Although in one of its aspect the present invention seeks to provide a diagnostic tool which is minimally intrusive into the appliance control system, that is not a wholly essential requirement and the invention envisages that optionally the diagnostic tool may incorporate or have associated therewith software or like means responsive to change of sound profile such that if that change is outside predetermined limits the appliance is either shut down or an alarm signal is generated.

The sound receiving transducer may be employed to facilitate monitoring of the frequency spectrum (i.e. sound signature) of a combustion flame. In normal operation the flame will generate sound comprising a plurality of frequencies, and monitoring may be undertaken to detect the

presence or absence and / or sound level of individual frequencies or band of frequencies.

The output means may be responsive to departure from the sound profile in the event of any single departure from that profile, whether a sound level, frequency or time interval departure, or may be adapted to be responsive, and provide an output signal, only in the event of two or more departures. The responsiveness may be a function, additionally or alternatively, of magnitude or number / frequency of occurrences of said departures.

The output means may monitor and be responsive to any departure from a pre-established sequence of sound signals which form part of a sound profile. The sound profile may be solely that from a single source of type of source (e.g. a gas burner or electro-mechanical relay switch) or from a plurality of sound sources or types of sound sources.

The energy conversion appliance may be of a kind which comprises the use of fluid, and the sound receiving transducer may be adapted to be responsive to sound generated by flow of said fluid. It may, for example, be responsive to the sound of flow of liquid or gas through a pipe, or for example flow of gas or liquid fuel to or through a combustion zone, or flow of combustion products from the combustion zone. The sound receiving transducer may be responsive to sound emitted by a heat transfer medium, for example water which flows through central heating radiators or air in a ducted air system. The invention is not, however, confined in use to monitoring of energy conversion appliances which comprise fluid flow. It may alternatively or additional be applied to energy conversion appliances which convert for example electrical power to mechanical movement or vice versa.

The invention envisages use of a single sound receiving transducer to receive signals from a plurality of sound resources. Those sound sources may all be contained in a single enclosure (e.g. the cabinet of a central heating boiler which may also contain a water pump) and said transducer may be located within that enclosure. The transducer may be located physically closer to a first or two sound sources if the sound level emitted by said first sound source during either a general, normal operational mode, or

during a (potential) defect mode is less that that from a second of the two sound sources.

Although the invention envisages use of a single sound receiving transducer to receive signals from a plurality of sound sources, that is not an essential requirement of the invention. The invention envisages that two or more sound receiving transducers may be provided each to receive sound from either a single or a plurality of sound sources. In the case of two or more sound receiving transducers, one may have characteristics different from the or each of the other sound receiving transducers. Thus one may be adapted to be preferentially sensitive to low frequency sound (such as that originating from a combustion flame) whilst another may be preferentially sensitive to high frequency sound (such as that generated by an electromechanical relay switch). If two or more sound receiving transducers are provided, they may be positioned alongside one another or separately located preferentially such that each is relatively near to that sound source which it is most advantageously adapted to detect.

The diagnostic tool and method of the present invention are not confined to the use exclusively of sound receiving transducers, and said sound transducers may be employed in combination with other types of transducer for provision of additional data which cannot be obtained by the use of a sound receiving transducer. Thus, for example, sound monitoring would not alone necessarily be appropriate to confirm that it is correct for a combustion flame to be operating continuously for a substantial period of time, and it may be deemed necessary to provide another type of transducer, such as a temperature sensor in the return flow of water from central heating radiators to a domestic boiler to establish whether or not the flame needs to be in said continuous operation.

The diagnostic tool may be employed to record the event sequence or sound profile when the boiler is known to be operating correctly and efficiently, for example immediately following a service, and use this sequence or profile, for reference, for comparison with subsequent measurements. Subsequent recordings of the data can be collected in a memory, preferably non volatile, in the diagnostic tool and used by the tool to

extract diagnostic information, or be made available, as a data stream, on a prescribed basis, to transmit over a communication channel to a local, or remote monitoring devise e.g. a computational system.

The diagnostic tool may be employed to monitor certain individual or combinations of, elements of an appliance where variations in the acoustic signature, with time, potentially provide significant diagnostic data. An example is the monitoring of a combustion flame to detect, for example, blockage conditions in the gas valve or monitoring of a fan to detect, for example, fouling of an impeller.

The diagnostic tool may be employed, in the event of a failure of an appliance or part thereof, to analyse the failure mode by reference to where in a sequence of events the failure occurred and extract significant diagnostic information, for example to identify a failed component.

One embodiment of the present invention will now be described, by way of example, with reference to Figure 2 which is schematic block diagram of a diagnostic tool in accordance with the present invention.

This embodiment of the invention relates to a use of a diagnostic tool for monitoring the operation of a gas fuelled central heating boiler of a domestic wet type central heating system.

The diagnostic tool comprises a sound receiving transducer in the form of a microphonic sensor (1) coupled to output means in the form of a sound recognition engine (2). The recognition system (2) is tuned and programmed to identify individual events within the sequence of events of a central heating gas boiler by recognising the acoustic signature of an event.

This acoustic sensor system can be used alone, or in conjunction with other (e.g. non acoustic) sensors to obtain diagnostic information about the appliance.

A non-volatile memory (3) is provided for storage of the processed data.

A processing unit (4) is provided as part of the diagnostic tool to process the data from the recognition engine (2) and to organise and store said data, in the memory, into a sequence of events with respect to time; to recognise a failure of the appliance and analyse the diagnostic information

associated with where in the sequence the failure occurred, initiate an alarm sequence and transmit an immediate alarm message; to monitor the acoustic signature of individual elements of components of the system and record variations in these signatures as diagnostic data or a measure of efficiency and to initiate and control the transmission of data to an external system.

A communication channel (5) is provided for communication of the diagnostic data to a local or remote computational system on an immediate, prescribed or regular basis.

CLAIMS

1 A diagnostic tool for an energy conversion appliance, said diagnostic tool comprising a sound receiving transducer coupled to output means to identify, discriminate and log the acoustic signatures of events within the operating sequence of an appliance.

2 A diagnostic tool according to claim 1, wherein the output means is an adaption of a type of voice recognition system.

3 A diagnostic tool according to claim 1 or claim 2, wherein the output means comprises means operated within the vicinity of an appliance.

4 A diagnostic tool according to claim 1 or claim 2, wherein the output means comprises means to transmit signals related to the acoustic signatures of events of within the operating sequence of an appliance to remote data processing means.

5 A diagnostic tool according to any of the preceding claims, and comprising means to generate an alarm signal.

6 A diagnostic tool according to any of the preceding claims, and comprising means to selectively shut down the appliance.

7 A diagnostic tool according to any of the preceding claims, and comprising a plurality of sound receiving transducers.

8 A diagnostic tool according to claim 7, wherein one sound receiving transducer has characteristics different from the or each of the other sound receiving transducers.

9 A diagnostic tool according to claim 8, wherein each sound receiving transducer has characteristics different from each of the other sound receiving transducers.

10 A diagnostic tool according to any of the preceding claims, and comprising one or more transducers responsive to signals other than sound.

11 A diagnostic tool according to claim 10, wherein said one or more transducers comprises a temperature sensor.

12 A diagnostic tool according to any of the preceding claims, wherein the sound receiving transducer is a microphonic sensor.

13 A method of monitoring an energy conversion appliance, said method comprising providing a sound receiving transducer and positioning said transducer to receive sound signals emitted by the appliance, and providing output means associated with said sound receiving transducer, said output means being responsive to the sound emitted by the appliance.

14 A method of monitoring an energy conversion appliance according to claim 13 and comprising establishing a sound profile which is concomitant with proper functioning of at least a part of the appliance.

15 A method of monitoring an energy conversion appliance in accordance with claim 14, wherein said output means is responsive to occurrences of the sound emitted by the appliance departing from said sound profile concomitant with proper functioning of at least a part of the appliance.

16 A method according to claim 15, wherein the output means is responsive only if the emitted sound lies beyond a threshold level.

17 A method according to any of claims 13 to 16, and comprising operating the output means within the vicinity of the appliance to

identify, discriminate and log the acoustic signatures of events within the operating sequence of the appliance.

18 A method according to any of claims 13 to 16, and comprising operating the output means to transmit signals related to the acoustic signatures of events within the operating sequence of the appliance to remote data processing means.

19 A method according to any of claims 14 to 18, and comprising establishing the sound profile of only one relationship between received sound and time.

20 A method according to claim 19, wherein said one relationship comprises the variation of sound level over a fixed time interval.

21 A method according to any of claims 14 to 18, wherein the sound profile encompasses a plurality of specific relationships all of which are concomitant with the proper functioning of the appliance.

22 A method according to any of claims 13 to 21, and comprising operating the output means regularly to transmit signals related to the acoustic signatures of events within the operating sequence of the appliance to remote data processing means.

23 A method according to claim 22, wherein the regular basis is once a day.

24 A method according to any of claims 15 or claim 16 to 23 when dependant on claim 15, and comprising operating an alarm when the output means responds to occurrences of the sound omitted by the appliance departing from said sound profile concomitant with proper functioning of at least a part of the appliance.

25 A method according to any of claims 15 or claim 16 to 23 when dependant on claim 15, and comprising shutting down the appliance when said output means responds to occurrences of the sound emitted by the appliance departing from said sound profile concomitant with proper functioning of at least a part of the appliance.

26 A method according to any of claims 13 to 25, and comprising providing a plurality of sound receiving transducers.

27 A method according to any of claims 13 to 26, and comprising providing one or more transducers responsive to signals other than sound signals.

28 A method according to claim 27, and comprising providing a transducer responsive to temperature.

29 Method accordingly to claim13 and substantially as hereinbefore described.

30 A diagnostic tool according to claim1 and substantially as hereinbefore described.

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Boiler Type	Typical		
Condition	Normal Operation	Sequence A	
Event Number	Event	Time	Comment
0			External Thermostats supply power
1	Power on	0	there is no permanent live on this boiler
2	Water flows	0	
3	Relay B operates	1	
4	Relay A operates	2	assumes PS ok, Boiler stat calls.
5	Fan Runs	2	
6	Air pressure switch operates	3	
7	Gas valve 1 operates	3	Pilot valve solenoid
8	Intermittent spark	4	
9	Pilot established	5	
10	Relay B de-energises	6	
11	Spark stops	6	
12	Gas valve 2 operates	6	Main gas valve solenoid
13	Main burner cross lights	7	
			Delay until boiler thermostat satisfied
14	Relay A de-energises	8	
15	Gas valve 1 De-energises	8	
16	Gas valve 2 De-energises	8	
17	Flames extinguished	8	
18	Fan stops	8	
19	Air pressure switch releases	9	
20	Relay B operates	10	
			Delay until Boiler thermostat calls
21	Boiler temperature sensor calls	11	
22	Power off	12	External thermostats satisfied.
23	Flames extinguished	13	
24	water flow stops	14	
25	Fan stops	15	
26	Relay A de-energises	16	
27	Air pressure switch releases	17	

Fig 1

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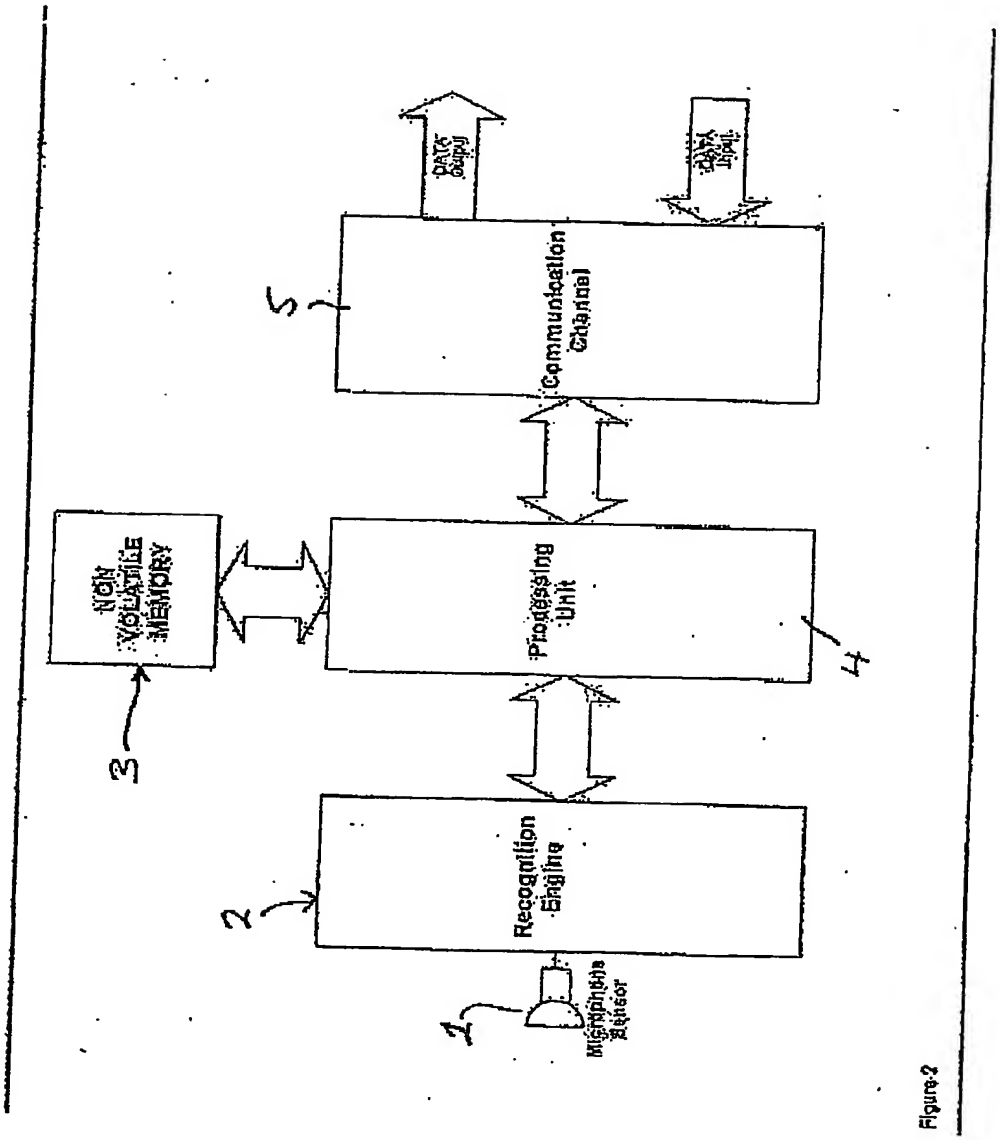
DATA OUTPUT
DATA INPUT
Communication Channel
5
NON VOLATILE MEMORY
Processing Unit
4
3
Recognition Engine
2
Microphone Receiver
1

Figure-2